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ECOLOGY OF THE HIGH PLAINS I

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Abstract

The climax vegetation of the high plains consists of subalpine woodland, sod tussock grassland, tall and short alpine herbfields, heaths, bogs and fen. Typical patterns of distribution are illustrated by reference to the Bogong High Plains area, and some comparisons are made with similar vegetation in New South Wales.

Relationships between the vegetation and habitat factors are described. These lead to hypotheses to explain the distribution of some of the communities.

Fires and grazing have produced various disclimaxes which, although satisfactory for continued extensive grazing, are inferior to the original climaxes for water yield.

Introduction

The vegetation is one of the most distinctive features of the high plains and provides the basis for defining them as ecological units. The characteristic transition from montane eucalypt forest to the more open communities of stunted snow gum, herbs and shrubs is usually complete within half a mile and often within a few yards. This change occurs near the lower level of persistent winter snow, which varies from about 4,500 to 5,000 ft depending on locality. Under special conditions of cold air drainage, pockets of high plains vegetation also occur at lower levels. The approximate distribution of the high plains vegetation thus defined is shown in Fig. 1. The total area is about 870 square miles, of which about 850 square miles occur within the altitudinal range of subalpine woodland (snow gum) and about 20 square miles, the alpine areas, occur above the tree line.

In the subalpine areas average annual precipitation varies from about 50 to more than 80 in., including snow which covers the ground continuously for at least 1 to 4 months; mean monthly temperatures reach about 50-55°F in January and fall to between 25-32°F in July. Precipitation probably exceeds 100 in. in some of the alpine areas and the snow cover persists longer; the mean temperatures for January and July are about 50 and 25°F respectively. Evaporation is probably between about 35 and 40 in. a year; the monthly values usually exceed precipitation during December, January and February, but the deficits are usually smaller than the calculated amounts of available water in the root zone of most adult plants growing on moderately deep soil (Costin 1961).

These average data are of general value for ecological work but they should be applied with caution. For example, leeward aspects receive up to twice as much snow as adjacent windward sites, and retain it up to several weeks longer. Consequently there is a wide range of micro-climates, especially on broken terrain, which is reflected in the complexity of the vegetation patterns. Other significant climatic effects not apparent from the standard data are the large number of ground frosts experienced during the snow-free months (cf. Foley 1945) and the frequency of mists and fogs in the more southern areas.

The Vegetation and Its Distribution

Published work on the ecology of the Victorian high plains includes various local botanical surveys (e.g. Garnet 1948, Morris 1929, Tadgell 1922, Wakefield

1953, Willis 1948), a detailed study of floristic changes in grassland following protection from grazing (Carr and Turner 1958b), and broader surveys of the vegetation especially in relation to land-use (Australian Academy of Science 1957, Carr and Turner 1959a, Costin 1957a, 1957b, Patton 1953). From these accounts the following summary of ecological units has been prepared (Table 1). The nomenclature used follows Beadle and Costin (1952) and Costin (1957a).

FIG. 1—Distribution of high plains vegetation in Victoria (stippled areas).

Typical patterns of vegetation distribution, as seen on the Bogong High Plains and the adjacent Mt Bogong and Loch-Hotham-Feathertop areas, are illustrated in Fig. 2. The order of accuracy is not high, and for mapping purposes it has been necessary to map complexes rather than the individual alliances (cf. p. 331). The zonation of montane sclerophyll forest, subalpine woodland and alpine herbfield (with heath) is most simply shown on the steeper, freely drained mountains such as Bogong, Loch, Hotham and Feathertop. On the gentler sloping Bogong High Plains this pattern is complicated by the extensive development of grassland and bog (mossbeds) in the basins and valleys.

The percentage distribution of the mapping units is approximately as shown in Table 2 (after Costin 1957b). Apart from the alpine herbfield communities which are less common elsewhere, similar distribution patterns are found in other high

TABLE 1

Climax Vegetation of the High Plains and Its Distribution

Structural Form or Subform	Alliance	Distribution
Sod tussock grassland	*Poa caespitosa-Danthonia nudiflora*	Widespread along valleys and in basins of cold air drainage, mainly in subalpine tract. Alpine humus soils, locally gley podzols and acid marsh soils.
Tall alpine herbfield	*Celmisia longifolia-Poa caespitosa*	Widespread above treeline on most freely drained, relatively deep alpine humus soils.
Tall alpine herbfield	*Brachycome nivalis-Danthonia alpicola*	Small occurrences on steep, relatively protected alpine slopes, and rock ledges.
Short alpine herbfield	*Plantago muelleri-Montia australasica*	Alpine snow patch situations with at least 8 months persistent snow cover. Snow patch meadow soils, acid fen peats.
Fen	*Carex gaudichaudiana*	Small occurrences in permanently wet, acid, almost level situations, influenced by mineral soil. Acid fen peats, acid marsh soils.
Valley bog	*Carex gaudichaudiana-Sphagnum cristatum*	As for fen, but more acid, and little or no influence from mineral soil. Bog peats.
Raised bog	*Epacris paludosa-Sphagnum cristatum*	Locally widespread in association with acid springs and seepages, both on level and sloping sites. Bog peats.
Heath	*Oxylobium ellipticum-Podocarpus alpinus*	Widespread on relatively rocky, exposed and usually more snow-free situations. Lithosols, alpine humus soils.
Heath	*Epacris serpyllifolia**	Ecotonal habitats between herbaceous vegetation and bog. Alpine humus soils, gley podzols.
Subalpine woodland	*Eucalyptus niphophila*	Subalpine climatic climax, widespread on most freely drained, relatively deep alpine humus soils, except along valleys and in basins of cold air drainage.

* Previously referred to as *Epacris serpyllifolia-Kunzea muelleri* alliance (Costin 1957). The name-change is desirable since *K. muelleri* is also an important component of the *Oxylobium-Podocarpus* heaths.

plain areas depending on whether they are predominantly plateaux like the Bogong High Plains, or steeper mountain peaks like Mt Bogong, etc. (for details see Costin 1957a).

A comparison of Table 1 with a similar table prepared for the high mountain vegetation of the mainland as a whole (Costin 1957a) reveals that the Victorian communities include all the forms and alliances other than the fjaeldmark vegetation of the Kosciusko area. Most of the association dominants listed in the Australian table are also well represented in Victoria. However, a few are not. These include *Themeda australis* Stapf., a common dominant of the sod tussock grasslands between 3,500 and 4,500 ft in the Kiandra area; the pendulous cline form of *Eucalyptus pauciflora* Sieb. ex Spreng. (Pryor 1956) in subalpine woodland also near Kiandra; and *Danthonia frigida* J. Vickery, an alpine herbfield dominant at Kosciusko. On the other hand, the Victorian herbfields contain distinctive associations of *Celmisia sericophylla* J. H. Willis as on Bogong, and of *Helipterum anthemoides* DC. as on the Crosscut Saw, whilst the subalpine woodlands of the Baw Baw Plateau

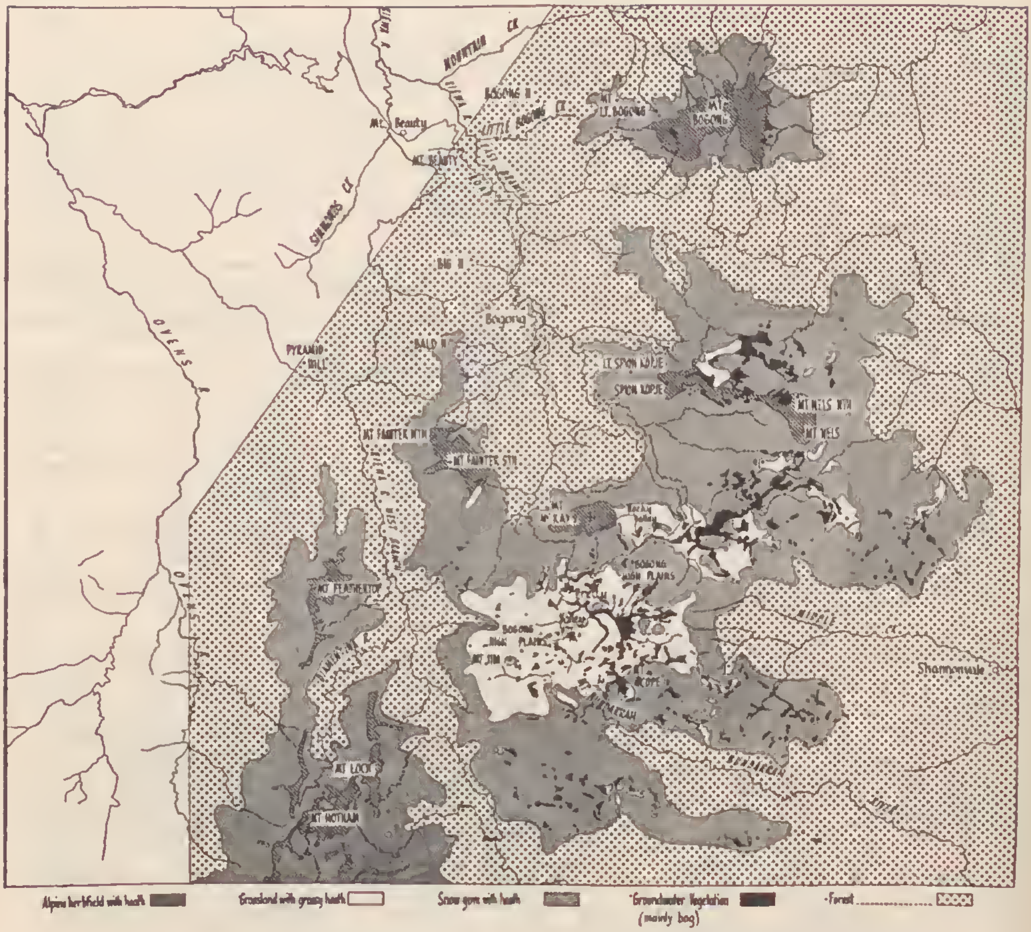

Fig. 2—Distribution of vegetation in the Bogong area.

contain *Nothofagus cunninghamii* Oerst. the myrtle beech. Some additional associations, common both to Victoria and New South Wales, should also be added (e.g. *Aciphylla glacialis* F. Muell. in herbfield), but more work is needed on the effects of grazing disturbance before definite decisions can be made. Improved taxonomic treatment of the *Poa caespitosa* complex would also lead to the recognition of several distinct *Poa* associations, instead of the one in grassland and one in herbfield as at present.

It is not proposed here to give descriptions of the individual alliances, or of changes in structure and floristic composition which fires and grazing have produced. This information is available elsewhere (e.g. Costin 1957a, 1957b). It should be emphasized, however, that as a result of grazing practices most of the existing vegetation is in a state of flux, and that this condition often complicates the classification of existing communities in terms of well defined structural and floristic groups. For example, aerial photographs of Rocky Valley on the Bogong High Plains taken in 1945 show some areas as grassland which are now grass-heaths.

TABLE 2

Percentage Distribution of Plant Communities in the Bogong Area

Unit	Bogong High Plains*	Mt Bogong†	Mt Loch-Hotham-Feathertop (in part)‡
Subalpine woodland with heath	76	72	87
Sod tussock grassland with grassy heath	9	Tr.	Tr.
Alpine herbfield with heath	10	28	13
Groundwater vegetation (mainly bog)	5	1	Tr.

* Maps A, B, C, D of 2″ = 1 mile Feathertop Sheet, Dept Lands and Survey, Victoria, 1950.
† Map B of Feathertop Sheet and Maps C and D of 2″ = 1 mile Tawanga Sheet, Dept Lands and Survey, Victoria, 1950.
‡ Map C of Feathertop Sheet.

Whether grazing is continued or not, it is likely to be many years before a general condition of relative stability is achieved.

The Vegetation and Critical Habitat Factors

The main objectives of field ecology are to describe and classify the vegetation, and to ascertain its distribution in relation to critical habitat factors. The last steps are the difficult ones and in the context of the Victorian high plains involve examining the habitat factors responsible for the following vegetation changes. Such an examination helps to develop hypotheses as a guide for more critical work.

Sclerophyll Forest — Subalpine Woodland
Subalpine Woodland — Alpine Herbfield/Heath
Sod Tussock Grassland — Subalpine Woodland/Sclerophyll Forest
Sod Tussock Grassland — Alpine Herbfield
Heath — Sod Tussock Grassland/Alpine Herbfield
Bog/Fen — Non-Groundwater Vegetation

SCLEROPHYLL FOREST-SUBALPINE WOODLAND

The transition from sclerophyll forest to subalpine woodland marks the beginning of high plains conditions. Where the increase in elevation is gradual, as from Omeo towards Hotham, the transition zone is broad and forest trees of *Eucalyptus pauciflora* grade clinally into woodland trees with the characteristics of *E. niphophila* Maiden and Blakely (cf. Pryor 1956). Where the increase in elevation is sharper, as from Harrietville towards Hotham, forest trees of *E. delegatensis* R. T. Baker and *E. dalrympleana* Maiden adjoin the *E. niphophila* communities. Although sudden breaks of slope, and differences in soil depth, exposure and fire history often accentuate the forest-woodland transition, the generally significant factors appear to be winter temperature and duration of snow cover. The limited meteorological data available indicate that snow gum will replace the forest species when a mean temperature of about freezing is associated with a continuous snow cover for more than one month. Mt Buffalo, 4,370 ft near the upper limit of *E. delegatensis*, has a mean July temperature of 34·5°F. The Kosciusko Hotel in N.S.W., at 5,020 ft at the lower limit of snow gum, has a mean July temperature just below 32°. With mean temperatures of about freezing, under Australian conditions, some of the snow usually melts during the day and the snow-pack becomes 'wet'; at night it freezes again. For *E. delegatensis* Grose (1961) has shown that seedling mortality is associated with saturation of the intercellular spaces of the leaves with water from melting snow. In laboratory trials death of water-saturated leaves occurred when the temperature was held at 33°F for about three weeks. In this regard the more glacous leaves of snow gum may effectively resist wetting and hence enable it to survive.

Subalpine Woodland-Alpine Herbfield/Heath

At about 5,500-6,000 ft, depending on latitude and local exposure, subalpine woodland, here reduced to scrub, is replaced by alpine herbfield or heath. Such tree-line conditions have attracted world-wide attention and various explanations have been proposed. In the northern hemisphere a generally satisfactory correlation has been found between tree-lines and a mean temperature of about 50°F for the warmest month (e.g. Polunin 1960). It has also been suggested that cold environments become uusuitable for tree growth when the mean wind speed 10 metres above ground level exceeds about 6 metres per second (Braun-Blanquet 1932). In Victoria a similar correlation with mean summer temperature may also exist. At Hotham Heights, which is just below the tree-line, the mean January temperature is about 52°F. At the Koscinsko Chalet, which is still closer to the tree-line, the temperature is about 50°. It is not clear whether tree growth is limited by the low summer temperatures themselves or by some correlated factor which has not yet been assessed.

There are, of course, several local factors which modify the actual level and position of trees in a general tree-line situation. Severe exposure to wind depresses the tree-line, as on isolated peaks such as Mt Cobbler (*c.* 5,340 ft) and Mt Wellington (*c.* 5,350 ft). By contrast, cliffs and very steep slopes are often protected by an air cushion which enables the tree-line to go higher: there are many examples in the Bluff-Mt Howitt area. Leeward slopes with more persistent snow are often treeless, although situated below the upper limit of trees, as seen on the Eskdale Spur of Mt Bogong. Conversely, relatively snow-free ridges extending beyond the general tree-line commonly support trees.

Sod Tussock Grassland-Subalpine Woodland/Sclerophyll Forest

Another type of tree-line exists on the lower slopes of broad valleys and basins. These valley tree-lines occur over a wider altitudinal range than the alpine-subalpine tree-lines just considered, from about 5,500 ft in the Bogong area down to 4,500 ft on the Bennison Plains. Descriptions of some typical topographic sequences on well drained sites assist in the analysis of this problem. The Bennison Plains, the southern valleys of the Buffalo Plateau, and the Bogong High Plains provide a series of increasing elevation.

The sequence from Mt Tamboritha (*c.* 5,380 ft) down to the Bennison Plains (*c.* 4,500 ft), a horizontal distance of about a mile, is subalpine woodland transitional to sclerophyll forest on the upper slopes, sclerophyll forest on the middle and lower slopes, with subalpine woodland fringing extensive sod tussock grasslands along the main valley. Where the slope is relatively steep, the lower subalpine woodland belt is telescoped, often to the point of elimination, so that sclerophyll forest and sod tussock grassland adjoin. It will be noted that the dominant vegetation is graded in terms of increasing cold in opposite directions, one from the middle to the top of the slope, and the other from the middle to the bottom of the slope.

On the Buffalo Plateau near the Horn, where the sequences are from about 5,500 to 5,000 ft, the sclerophyll forest belt does not occur and subalpine woodland occupies all but the lower sites where sod tussock grassland still remains.

At Pretty Valley on the Bogong High Plains, the general level is about 5,500 ft, with surrounding peaks rising to 6,000 ft. Here the zonation of tree and grassland vegetation is less regular than in the sequences at lower elevations (cf. Fig. 2). The grassland communities are far more extensive, covering not only the floor and lower slopes of the main valley but extending up the broad subsidiary valleys to the watersheds. Consequently the subalpine woodland vegetation, although generally zoned to the upper and middle slopes, has an irregular distribution especially on gentler terrain where it is often reduced to small islands of stunted trees on locally higher sites. The most extensive belts of trees occur where the upper slopes are relatively steep, as on Mt Cope and the northern section of the Rocky Valley-Pretty Valley Divide.

The common feature of these sequences is for the more cold-tolerant vegetation to occur in the lowest topographic sites. The existence of frost pockets is well known and it is common experience on the high plains that the treeless valleys are colder than the tree-covered slopes. Actual temperatures have been measured by Moore (1958) in the Currango area of New South Wales, which is similar to the Bennison Plains. Fig. 3. prepared from Moore's data, shows typical temperature patterns across the valley, as determined 2 ft 7 in. above ground level. Moore also planted out young trees of the three tree-line species at Currango, *Eucalyptus pauciflora*, *E. rubida* Deane and Maiden and *E. stellulata* Sieb. ex DC., and found that those planted below the tree-line died. Subsequent work by C. W. E. Moore (1959) showed that the nutrient status of the woodland and grassland soils is essentially similar. There is thus reasonable evidence for concluding that the absence of trees from the valleys is due to the lower temperatures caused by cold air drainage. The lower temperatures are probably most critical in spring and summer during the seedling stage.

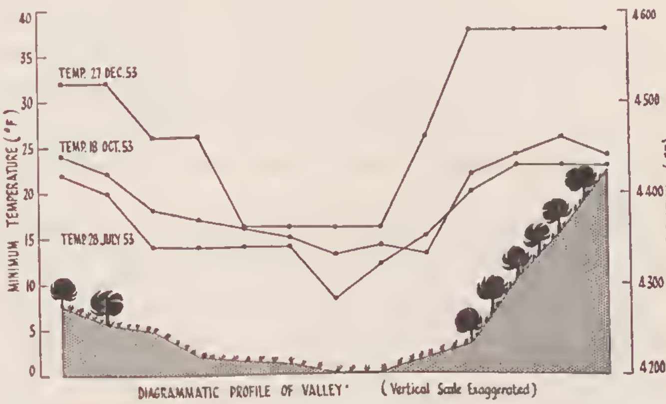

FIG. 3—Relationship between vegetation and minimum temperatures across valley.

Sod Tussock Grassland-Alpine Herbfield

The main distinction between alpine herbfield and sod tussock grassland is the greater abundance of conspicuous forbs, especially *Celmisia longifolia* Cass., and to a less extent *Aciphylla glacialis*, in the herbfield communities. Floristic separation in the field is usually facilitated by spatial discontinuities: the grasslands are more common within and below the snow gum belt and the herbfields above the tree line.

The differentiating habitat factors appear to be duration of snow cover and length of the growing season; however, the responses of herbfield and grassland species to variations in these conditions have not yet been critically examined.

The above distinctions cannot always be readily made, as in Pretty Valley on the Bogong High Plains. Pretty Valley is situated at a higher comparative level than most similar valleys in Victoria and New South Wales, and this is reflected in the rather large component of alpine forbs in the grassland vegetation. In one area protected from grazing for ten years, the proportion of forbs, especially *Celmisia longifolia*, has greatly increased, and the protected community is now herbfield rather than grassland in character (Carr and Turner 1959b). Whether this represents an intermediate condition in a slow process of grassland recovery or whether it is climax herbfield remains to be seen. An important need in the study of high plains vegetation is illustrated, however, namely the determination of characteristic and differential species by which such border-line communities can be objectively and consistently classified.

Heath-Sod Tussock Grassland/Alpine Herbfield

Another difficult situation is the relationship between heath and herbaceous vegetation, especially herbfield. As indicated in Table 1, there are two main heath communities, one of relatively exposed or freely-drained rocky situations (*Oxylobium ellipticum-Podocarpus alpinus* alliance) and the other (*Epacris serpyllifolia* alliance) on deeper, poorly drained soils usually transitional to bog. It has also been established that exposure of bare ground in herbaceous communities facilitates invasion by shrubs which may remain for at least 50 years (Costin, Wimbush, Kerr and Gay 1959).

Apart from these situations extensive mixtures of heath and herbfield are common as a low- alpine belt just above the tree-line, as on Mt Buller and Stirling and on parts of Mt Bogong and McKay. *Hovea longifolia* (auct. non R. Br.) is usually the most important shrub, on a scale not paralleled in the more extensive alpine areas of New South Wales. Closer examination of the *Hovea*-herbfield zone frequently reveals a mosaic pattern, with *Hovea* on the slightly raised or rocky sites and herbfield in between. With increasing elevation the *Hovea* thins out leaving mainly herbfield, an effect which is clearly shown on the south-eastern slopes of Mt Buller.

The habitat differences which appear to be important are local exposure, soil depth, and duration of snow cover. These influences often vary in the same direction. The more exposed sites accumulate less snow and have shallower, stonier soils; this favours shrubs. The more protected sites accumulate more snow and have deeper, relatively stone-free soils; these conditions favour herbaceous species. With increasing elevation there is also more snow, and this likewise favours herbs.

The greater importance of low-alpine heath, especially *Hovea* communities, in Victoria than in New South Wales is related to differences in land form. The alpine areas of Victoria are mainly peaks which are relatively steep, rocky and exposed. The New South Wales areas are largely plateaux with deeper soil and generally more persistent snow.

The preference of shrubs for the more rocky and exposed situations has interesting implications as regards the probable sequence of the original plant successions. Herbs are generally regarded as an earlier stage than shrubs but in the high plains at least it is likely that shrubs (and even trees) were the pioneers. Similar conclusions have been reached on the Wasatch Plateau of the U.S.A. (Ellison 1954).

BOG/FEN-NON-GROUNDWATER VEGETATION

The main factor differentiating bog and fen communities from the rest of the vegetation is permanent wetness of ground, due either to springs or to a high water table. These wet conditions can be extended further by the expansion of the bog or fen, but this is a secondary effect. The surrounding communities are usually heaths of the *Epacris serpyllifolia* alliance or grassland characterized by the rigid-leaved ecotype of snow grass. In New South Wales the differentiation between bog and fen has been related to the acidity of the ground waters (Costin 1954). Field observations indicate similar relationships for Victorian conditions, although these have been much obscured by the vegetation changes associated with grazing.

The Vegetation and Its Utilization

In the modern world few ecological studies are complete without reference to the human factor. The effects of different types of land-use on the vegetation, and the suitability of the vegetation for different types of land-use, should be determined. On the Victorian high plains, grazing and water supply are the main considerations in this respect, and recreation is also becoming important.

Briefly, fires and grazing have caused a general opening up of the herbaceous communities with a corresponding increase in shrubs, minor herbs and bare ground; the replacement of much of the original snow gum vegetation by denser regrowth scrub; and the drying out of ground water vegetation (e.g. Costin 1957b). From the viewpoint of utilization, two distinct but overlapping stages can be recognized. The first was mainly one of selective grazing of the palatable major herbs leaving a pasture consisting more predominantly of the unpalatable snow grasses. As the palatable herbs were progressively removed a variety of shrubs and minor herbs, both native and introduced, took their place. These minor herbs provide most of the usable pasture under the second stage of grazing which exists today. In view of the susceptibility to grazing of many of the original herbs, a permanent system based on the original climax is difficult to visualize, since under extensive grazing conditions selective utilization cannot be prevented (Costin 1958). Unless sown pastures are established, therefore, high plains grazing must depend on holding secondary succession at the minor herb stage.

The value of vegetation for water supply purposes is assessed in terms of its effect on quality, regime and quantity of stream flow. Experiments in the Snowy Mountains (Costin, Wimbush and Kerr 1960) have shown that a continuous herbaceous cover at the rate of about 0·2 lb. per sq. ft oven dry weight promotes optimum infiltration and minimizes soil loss; this is the typical condition of the natural vegetation. The secondary heaths also promote good infiltration but are less effective in preventing soil loss. The widespread snow grass-minor herb communities are least effective in preventing surface run-off and soil loss; these provide ground cover at the rate of 0·1-0·02 lb. per sq. ft. On the basis of visual estimates, most of the grazed vegetation of the Victorian high plains would fall into this class.

Tree vegetation, although relatively ineffective in minimizing surface run-off and soil loss, is important for high and sustained water yield. Data from the Snowy Mountains can be directly applied to Victorian conditions. Snow gum vegetation accumulates up to 50-100% more snow water than adjacent treeless communities; moreover, the snow melt period extends up to a month longer, not being complete until after the main spring thaw. A rather open, overmature woodland also collects more snow and retains it longer than dense regrowth scrub. Furthermore, precipitation from windy rains, fog and cloud is at least 10% greater under trees than on open ground (Costin, Gay, Wimbush and Kerr 1961; Costin and Wimbush 1961).

The hydrological role of the bog vegetation is more complex than originally believed. Because of the lag between air and subsoil temperature, the springs and ground waters entering the bog are relatively warm in winter. Provided the bog is not drained by gullies or creeks, the warmer water is spread across the whole bog and snow melt thus occurs before the snowpack on non-ground water vegetation has matured. The resultant increase in stream-flow in winter, which on the high plains is a period of low flow, is advantageous for the generation of electric power. The hydrological significance of the bogs in summer has not yet been fully assessed. It seems certain, however, that higher quality water will be produced from catchments in which the bogs are undamaged, since much of the stream flow filters through them.

These data show that a rather sparse cover of trees, underlain by a dense ground cover of herbs, with numerous bogs below springs and along the valleys, is most suitable for maximum regulated flow of high quality water. This type of vegetation has not been maintained under grazing. In fact, the most important catchment species, snow grass, is largely unpalatable, and existing grazing depends on maintaining the vegetation in a subclimax condition.

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